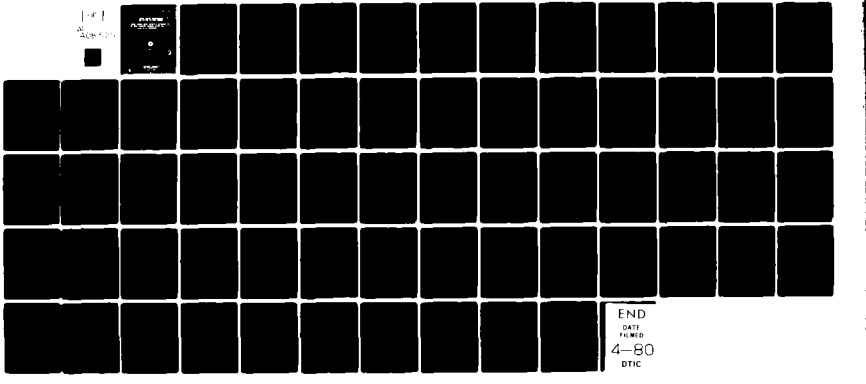
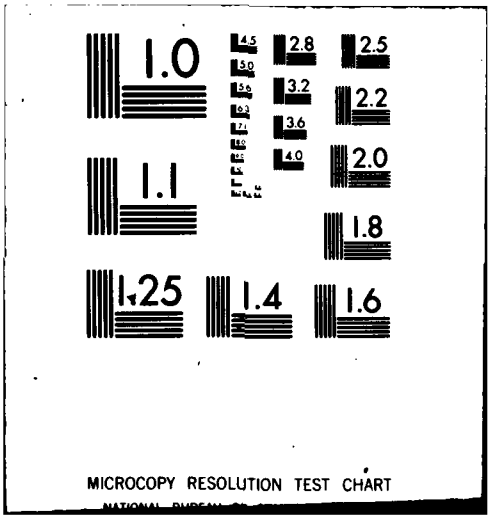
AD-A081 520 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC OFFICE --ETC F/G 13/2
FEDERAL AVIATION ADMINISTRATION HIGH ALTITUDE POLLUTION PROGRAM--ETC(U)
DEC 79 N SUNDARARAMAN, W SMITH, J ROGERS

UNCLASSIFIED FAA-EE-79-24

NL



END
DATE FILMED
4-80
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
MICROCOPY RESOLUTION TEST CHART

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-EE-79-24		

4. Title and Subtitle	5. Report Date
FEDERAL AVIATION ADMINISTRATION HIGH ALTITUDE POLLUTION PROGRAM, SECOND BIENNIAL REPORT PREPARED IN ACCORDANCE WITH THE OZONE PROTECTION PROVISION, SECTION 153(g), OF THE CLEAN AIR ACT AMENDMENTS OF 1977.	Dec 1979
	6. Performing Organization Code: AEE-300
7. Author(s): N. Sundararaman, W. Smith and J. Rogers	8. Performing Organization Report No.: FAA-EE-79-24
9. Performing Organization Name and Address: U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, High Altitude Pollution Program, Washington, D.C. 20591	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered: Biennial Report. Jan 1978 — Dec 1979
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This is the second biennial Federal Aviation Administration (FAA) report prepared in accordance with the Stratospheric Ozone Protection provisions of Public Law 95-95, the Clean Air Act Amendments of 1977.

The impact of high altitude aviation on stratospheric ozone is now believed to be an increase in total columnar ozone for flights up to 20 km (about 66,000 feet). This result has been brought about through improvements in one-dimensional chemical kinetics-transport models of the stratosphere. They show that aircraft-injected pollutants (primarily nitrogen oxides) generate ozone through simplified "smog" mechanisms in the upper troposphere and lower stratosphere while depleting it through the classic catalytic destruction mechanism at higher altitudes. The net result at present is a slight overall ozone increase.

The uncertainty in the present model calculations, however, is unknown.

The effort of the High Altitude Pollution Program of the Federal Aviation Administration is aimed at identifying and resolving the uncertainties so that a "consensus" method or methods can be obtained for future assessments of the impacts of high altitude aviation on the environment.

17. Key Words	18. Distribution Statement
Upper atmospheric pollution by aircraft High Altitude Pollution Program Ozone change from aircraft emissions	This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

LIST OF FIGURES: Page

SUMMARY

This is the second biennial Federal Aviation Administration (FAA) report prepared in accordance with the Stratospheric Ozone Protection provisions of Public Law 95-95, the Clean Air Act Amendments of 1977.

The impact of high altitude aviation on stratospheric ozone is now believed to be an increase in total columnar ozone for flights up to 20 km (about 66,000 feet). This result has been brought about through improvements in one-dimensional chemical kinetics-transport models of the stratosphere. The improvements have consisted of including (1) odd chlorine chemistry, (2) simplified tropospheric methane oxidation ("smog") chemistry and (3) recent revisions in chemical rate constants. The cumulative effect of these improvements is that aircraft-injected pollutants (primarily nitrogen oxides) generate ozone through simplified "smog" mechanisms in the upper troposphere and lower stratosphere while depleting it through the classic catalytic destruction mechanism at higher altitudes. The net result at present is a slight overall ozone increase.

The uncertainty in the present model calculations, however, is unknown.

The greatest uncertainty for the aircraft problem is the inherent inability of one-dimensional models to resolve the latitude dependence of the effects. For, while one-dimensional models allow variation of atmospheric properties (such as temperature, motion and trace species concentrations) only in the vertical dimension, both the natural ozone distribution and the aircraft injection are altitude and latitutde dependent. Thus two-dimensional models, which include variations of atmospheric properties across the latitudes, are needed for reliable assessments of aircraft effects.

In addition, the following factors contributing to uncertainties in model calculations have been identified:

(1) Pressure and inverse temperature effects on bimolecular radical - radical reactions.

(2) Lack of adequate data for reaction rates in methane oxidation chemistry.

(3) Lack of atmospheric data on odd nitrogen species (e.g., nitrogen oxides) and partitioning among them for quantifying relative increases, over background levels, due to aircraft operations and for verifying model predictions.

The effort of the High Altitude Pollution Program of the Federal Aviation Administration is aimed at resolving these uncertainties so that a "consensus" method or methods can be obtained for future assessments of the impacts of high altitude aviation on the environment.

1.0 INTRODUCTION

This is the second biennial report of the Federal Aviation Administration (FAA) submitted in accordance with P.L. 95-95 and brings to date all activities since the last report of December 1977. The current understanding of the effects of high-altitude aircraft operations on atmospheric ozone and climate is discussed and the role played by the FAA in associated research is reviewed.

Large scale commercial aircraft operations were first implicated as a possible environmental threat in 1971 during Congressional hearings on the development of the supersonic transport (SST). At that time, the concern was primarily focused on the possible effects of water vapor in exhaust emissions. It was hypothesized that water vapor injected directly into the stratosphere, would enter into a catalytic cycle of chemical reactions resulting in a reduction in the amount of stratospheric ozone. Two corollary arguments followed and these still continue to have qualitative validity up to the present:

(a) Any ozone reduction would permit an increase in the amount of biologically harmful solar ultraviolet (UV) radiation at the earth's surface;

(b) Any increase in such radiation has the potential for increasing the incidence of skin cancer in fair-skinned human populations.

Other fears were also expressed that water vapor, by increasing high altitude cloudiness, may adversely impact the earth's climate.

In March 1971, Congress voted to discontinue funds for the SST development program. Congress also directed the U.S. Department of Transportation to undertake a comprehensive program to assess the environmental impact of future supersonic flight. This program, known as the Climatic Impact Assessment Program (CIAP), was concluded in 1975 with the issuance of a Report of Findings [1]. Concurrently an independent study [2] was conducted by the Climatic Impact Committee of the National Research Council (NRC).

During the course of these studies, and parallel studies in Great Britain [3] and France [4], however, species of potentially far greater nitrogen (NO and NO_2, or NO_x collectively), emitted as a result of combustion at high temperatures, could participate in a catalytic cycle, as had been similarly theorized for water vapor, and result in a depletion of stratospheric ozone. The consequences of such a reduction were, again, potential increases in biologically harmful solar UV radiation and an increase in the incidence of skin cancer.

During CIAP, attempts were also made to quantify possible climatic effects resulting from the emission of sulfur dioxide (SO_2) originating from the sulfur content of the aviation fuel. The successive oxidation of SO_2 results in solid sulfate particles which affect the radiation balance, and hence the thermal balance, of the atmosphere and the earth.

The ozone depletion problem was thought to be more amenable to quantitative calculations and thus one lending itself to solution through regulatory remedies. Some estimates were also made of potential changes in the earth's mean surface temperature in the CIAP Report of Findings(1).

The CIAP and the NRC studies, in addition to confirming the original hypothesis that the potential did indeed exist for adverse environmental effects from NO_x emissions from large fleets of SSTs, showed that existing and (then proposed) higher-flying subsonics had similar potential. Thus, all aircraft operations, regardless of cruising altitude, could deplete stratospheric ozone. Both studies recommended immediate efforts for regulating future stratospheric flights and for accelerated research on developing engines with low emissions of NO_x.

The (subjective) uncertainties in the CIAP and NRC calculations for ozone depletion were such that regulatory options could not be immediately developed. In order to examine the immediacy of the need for such regulations and also to formulate them in a timely manner, the Federal Aviation Administration formed the High Altitude Pollution Program (HAPP) to quantitatively determine the requirements for reduced cruise-altitude emissions (5). The overall objective of HAPP is to reduce the remaining uncertainties in the predicted effects of high altitude aircraft emissions and, in conjunction with the Environmental Protection Agency (EPA) and the International Civil Aviation Organization (ICAO) to ensure that, if necessary, appropriate regulatory action is taken to avoid environmental degradation.

2.0 CURRENT UNDERSTANDING OF THE EFFECTS OF CRUISE ALTITUDE AIRCRAFT EMISSIONS

The stratosphere became the object of integrated and coordinated multidiscipinary scientific federal study under CIAP for the first time. Prior to CIAP, sparse data had been collected on the trace species in the stratosphere, important chemical rate constants were not well known, and stratospheric models, used for estimating future impacts, were in initial stages. During CIAP, a prolific development in all three areas was achieved. However, the scientific understanding of the stratosphere resulting from the CIAP study was profoundly influenced by later findings arising from the consideration of other environmental perturbations.

2.1 Scientific Understanding of Aircraft Effects Resulting from CIAP.

In view of the fact that actual measurements of atmospheric species (such as ozone) and their increase or decrease resulting from anthropogenic influences can never be used in a predictive sense, numerical models of the statosphere have been used by CIAP, HAPP and other studies, as fundamental assessment tools. Such models were developed with varying degrees of sophistication. In a one-dimensional (1-D) model the atmospheric properties are averaged in both the longitudinal and latitudinal directions and explicitly only the vertical variations are allowed. Two-dimensional models are expanded to include explicit descriptions of latitudinal variations. Three-dimensional models attempt to describe atmospheric motions and other properties in all three dimensions. Although all models include chemical transformations, generally the completeness of the chemistry varies inversely with the dimensionality of the model.

During the CIAP investigation, only 1-D models were sufficiently developed in the treatment of chemistry to be used for assessment purposes. The set of chemical equations used for input in the CIAP models was based on the O_x (oxygen containing constituents such as O_3 and O), and NO_x (nitrogen containing constituents such as NO and NO_2), and HO_x (hydrogen containing constituents such as HO and HO_2) cycles. With such a set of reactions, NO_x provided the most important sink for ozone in the natural stratosphere. Hence, addition of NO_x from aircraft exhaust necessarily led to a decrease in stratospheic ozone.

At the close of CIAP in 1975, the best models and input data indicated that a fleet of 120 "Concorde-like" aircraft would reduce stratospheric ozone in the Northern Hemisphere* by 0.5 percent. This 0.5 percent Northern Hemispheric decrease was thought to be the "minimum detectable" change(1) and hence an arbitrary choice. (To date, no regulatory agency nor scientific body has proposed any other acceptability criterion.) The High Altitude Pollution Program of the FAA subsequently adopted 0.5 percent Northern Hemispheric ozone decrease as its criterion for developing regulatory options, in the absence of any other recommendation; thus, future fleet projections which would otherwise exceed this 0.5 percent level, could lead to statutory requirements for reduced NO_x emissions.

It was recognized at the close of CIAP that substantial uncertainties were present in all elements of the assessment. For example, using the same data base, the National Research Council estimated that the 120 "Concorde-like" aircraft would result in a 0.9 percent ozone reduction in the Northern Hemisphere. Thus, improvements in the chemical rate data base and further model refinements were required before a reliable assessment could be made for regulatory purposes.

*The 0.5 percent change in Northern Hemispheric Ozone was equivalent to 0.25 percent change in global ozone; the ratio of Northern Hemispheric change to global change was taken to be 2 to 1 (1, 2).

2.2 Changes in Scientific Understanding Since CIAP.

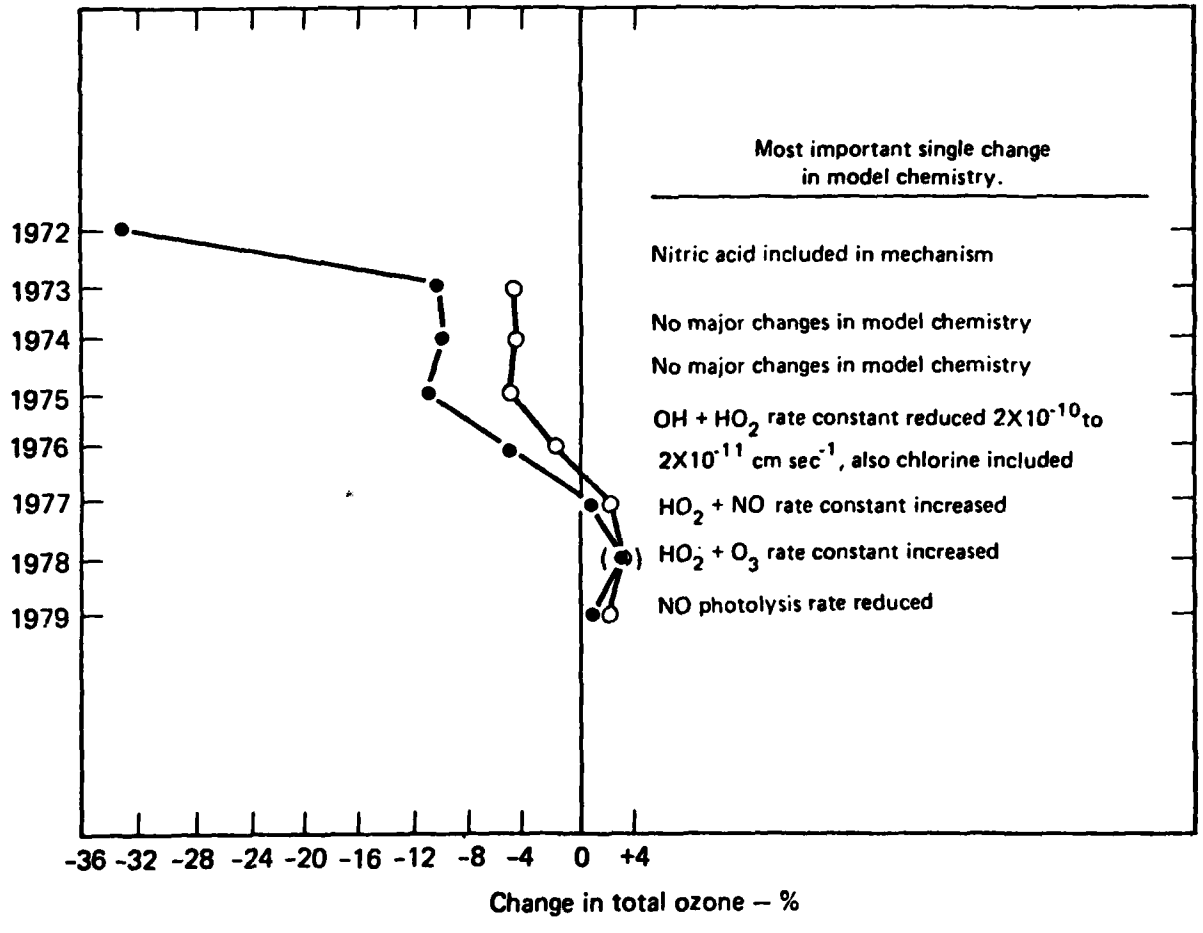
The improvements which were foreseen and planned upon, in addition to other improvements resulting from unforeseen developments, have led to substantial changes in the predicted effects of NO_x injections on stratospheric ozone. These changes, it will be seen, have altered even our qualitative understanding of aircraft effects. Figure 1 shows the response of a typical 1-D model to chronological changes in chemical input data. The injection scenario represents a canonical fleet where the total NO_x injection is fixed rather than number of aircraft. (Using the aircraft characteristics assumed during CIAP, however, this injection scenario corresponds to approximately 2,200 "Concorde-like" aircraft.* This rather large injection rate was chosen for ease of calculation.)

(A) The most dramatic change in the computed effects of NO_x injections as quantified during CIAP was presaged by the realization in 1974 that chlorinated inorganic compounds such as CF_2Cl_2 and $CFCl_3$ could by photodissociation inject ClO_x (Cl and ClO) radicals directly into the stratosphere. Although the principal scientific concern was focused on the extent of ozone depletion which ClO_x itself would cause, it soon became clear that the presence of chlorinated radicals in the stratosphere substantially altered the sensitivity of stratospheric ozone to NO_x. This effect results directly from the fact that such chlorine containing radicals also react with NO_x species to "short-circuit" the otherwise repeating (i.e., catalytic) cyclic reaction sequence. The extent to which ClO_x ameliorates the NO_x destruction of ozone depends quite sensitively on the total amount of ClO_x in the atmosphere. At the present time, the ClO_x concentration is not well known and, in some cases, inconsistent with theoretical upper bounds.

Although, as seen in Figure 1, several changes in reaction rate coefficients have affected model results, two particular changes have had profound effects. These are the disproportionation of the hydroxyl radical (OH) with the perhydroxyl radical (HO_2) and the reaction of nitric oxide (NO) with the perhydroxyl radical (HO_2). Until 1977, when the technique of laser magnetic resononce (LMR) spectroscopy first found practical application, reactions involving HO_2 were studied indirectly and usually under complex laboratory reaction conditions. This species is of particular importance to the aircraft problem since it drives the

*The NO_x injection considered is 2,000 molecules of NO per cm^3 per sec. over a 1 km altitude interval centered about the cruise altitude. This is equivalent to 1.24×10^9 kg per year as NO_2. With a CIAP "Concorde-like" aircraft defined as (a) having an emission index of 18g (NO_2) per kg of fuel burned, (b) cruising for 4.4 hrs. a day every day of the year (365 days), and (c) using 19,100 kg of fuel per hour at cruise, this injection rate corresponds to a fleet of 2245 "Concorde-like" aircraft. Such correspondences can be misleading, of course, since 2,000 aircraft flying at 15 km would have quite different effects from the same number flying at, say, 20 km. The fleet sizes are given here for illustrative purposes only. The effects of projected fleets will have to be assessed for each scenario independently.

FIGURE 1



The historical evolution of a typical model calculation (The Lawrence Livermore 1-D model) of the change in total ozone due to a NO_x injection of 2,000 molecules cm^{-3} s^{-1} over a 1 km thick layer centered at either 17 km (open circles) or 20 km (solid circles).

conversion of catalytically-active NO to nitrogen dioxide (NO_2) and eventually to nitric acid (HNO_3) which is removed by rainout and thus is inactive in the ozone depletion scheme. By means of LMR spectroscopy, several reactions of critical interest involving HO_2 can now be directly studied. Results thus far have revealed substantial uncertainties in the chemical rate data base and have further demonstrated that even rate constants which are thought to be "well known" at any given time can be greatly in error.

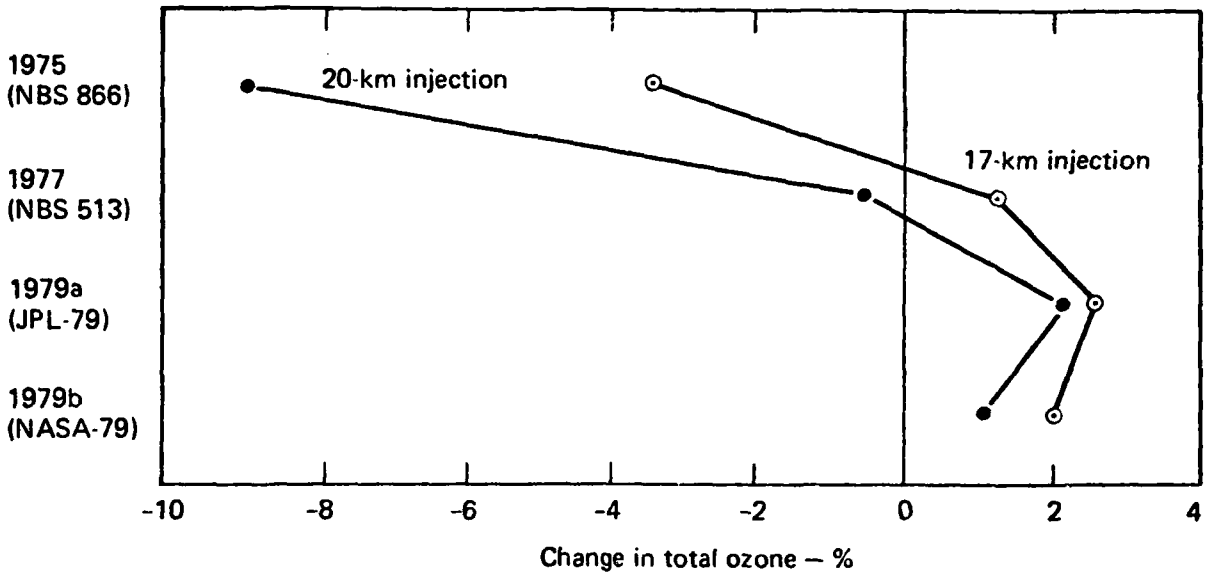
At present, the number of chemical reactions important to aircraft effects appear to be expanding while existing data are continually undergoing revision. Thus, there is reason to believe that further changes may occur in the future. Figure 2 chronicles the change in model output for a given set of reactions (including HO_x, NO_x, O_x, and ClO_x) as the rate coefficients have undergone formal revision. The last two points, only several months apart, demonstrate that complete reversals in trend can abruptly occur.

(B) In addition to the inclusion of chlorine and several rate coefficient revisions, realization of the importance of methane oxidation chemistry and its inclusion in the models in the overall assessment of aircraft effects was another significant change. Methane oxidation constitutes an important chemical cycle in the troposphere and lower stratosphere. Although some preliminary consideration was given to such tropospheric effects during CIAP, its final assessments did not include the troposphere or methane oxidation. It was felt the data base for such chemical interactions was not sufficiently well developed to include them in any reliable assessment.

As NO_x is injected or transported into a region containing methane (of natural origin), it becomes a catalyst for the production of ozone just as in urban smog episodes. Thus, as seen in Figure 3, injection of NO_x from aircraft results in the decrease of ozone in the upper stratosphere but an increase in ozone in the lower stratosphere and troposphere. The net effect, as measured from the ground, is now computed to be an overall increase in column ozone for any reasonable fleet projection. For a HAPP-projected 1990 fleet of subsonic and supersonic aircraft, Figure 4 shows that a substantial increase in tropospheric ozone can occur. The net column increase is on the order of 2.0 percent. Of this, 1.86 percent is due to the subsonic component of the fleet alone.

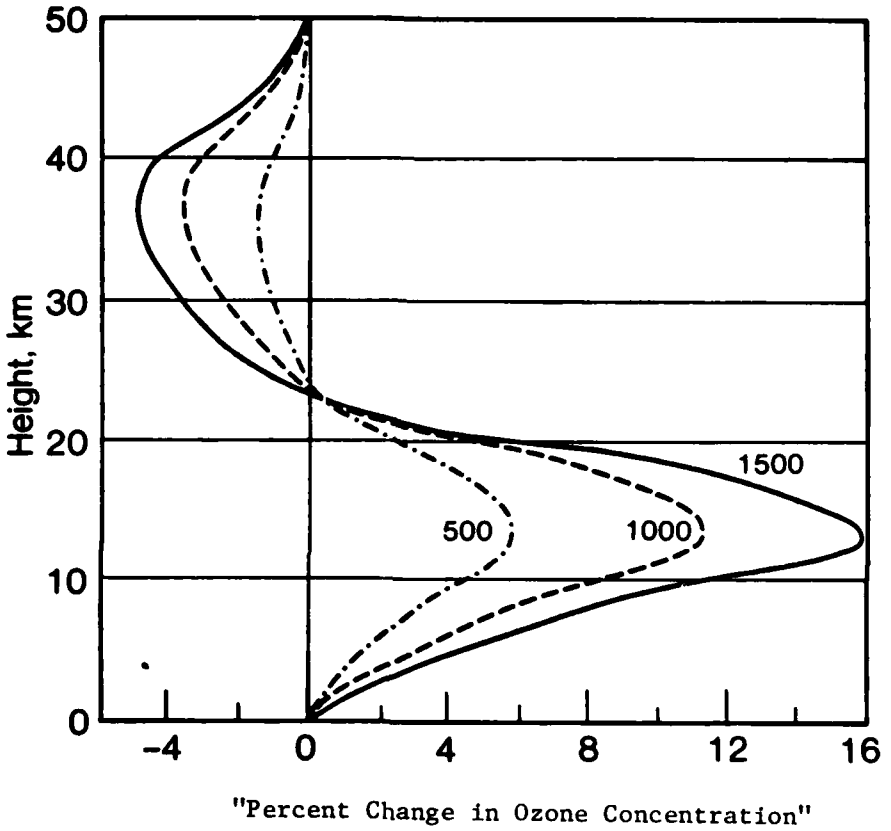
To summarize, recent developments in laboratory chemical investigations and improvements in atmospheric modeling have substantially modified our understanding of the atmosphere as it existed at the end of CIAP. These developments demonstrate two important points:

FIGURE 2



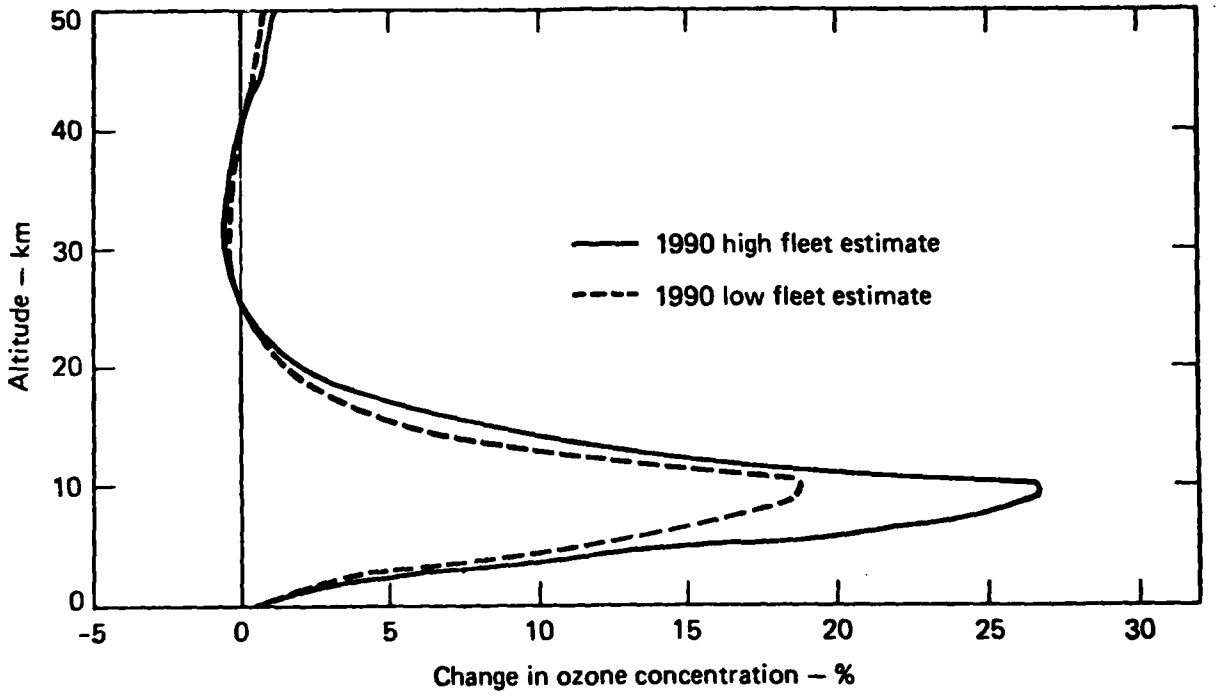
The change in total ozone due to the NO_x injection of Figure 1 using 1-D models with variations in model chemistry corresponding to various sets of rate recommendations.

FIGURE 3



Percentage change in ozone vs. altitude for three injection rates (in molecules $cm^{-3}s^{-1}$) over a 1 km band at 20 km.

FIGURE 4



The percentage change in ozone concentration due to the HAPP-projected 1990 high and low fleet estimates.

(1) Existing atmospheric models tend to show a smaller effect on atmospheric ozone than the CIAP estimates for both current-type supersonic and subsonic aircraft, with most models now showing a slight increase in ozone; and

(2) The uncertainty in model predictions from CIAP and other parallel programs was an underestimate and greatly emphasizes the necessity to reevaluate present model uncertainties in a more realistic fashion.

Inasmuch as column ozone depletion and considerations of skin cancer incidence no longer provide a rationale for a mandated reduction in NO_x cruise altitude emissions, no regulations for this purpose are now being contemplated. However, the FAA remains keenly aware of the possibility that this current understanding may change.

3.0 REMAINING UNCERTAINTIES IN THE EFFECTS OF CRUISE ALTITUDE EMISSIONS

Identification of the remaining uncertainties in the predicted environmental effects of cruise altitude emissions and the elimination, or quantification where possible of those uncertainties, constitutes the major objective of HAPP. The best way of attacking the uncertainties is to identify those associated with the modeling elements of (1) atmospheric chemistry, (2) atmospheric dynamics and transport, and radiation processes, (3) sensitivity of NO_x perturbations to others such as ClO_x, and (4) aircraft exhaust emissions. To this end, systematic studies have been undertaken in laboratory chemistry, modeling, and stratospheric field measurements.

3.1 Uncertainties in Atmospheric Chemistry.

3.1.1 Uncertainties in Chemical and Photochemical Input Data.

The single greatest uncertainty in the chemical rate coefficient data base concerns the class of interactions of important radicals with the hydroperoxyl radical (HO_2). With the introduction of technological advances (e.g., LMR technique mentioned earlier), capable of directly detecting and studying HO_2 radicals, many reactions which have been remeasured have resulted in a substantial revision in the quantitative predictions of NO_x, ClO_x, or HO_x injections. Although these newer studies are performed under carefully controlled reaction conditions and are direct studies (as opposed to earlier indirect studies), a great deal of uncertainty yet exists. Specifically, on the basis of available sparse data, the dependence of the rate coefficients on temperature and pressure shows anomalous behavior. That is to say, the rates of some reactions appear to decrease with increasing temperature and also exhibit some dependence on pressure, neither characteristic of bimolecular

direct disproportionation mechanisms. This appears to indicate that some reactions may necessitate the use of rate coefficients which actually change as a function of altitude, a property not currently included in any models. Thus, there is a growing awareness that more diagnostic and/or mechanistic studies must be performed for some reactions and the specific pressure and temperature variations must be directly quantified.

Another significant uncertainty which is of great relevance to the aviation problem relates to the methane oxidation or "smog cycle" reactions. These account for the NO_x-generated increase in ozone in the troposphere and lower stratosphere and thus counteract what would otherwise be ozone depletion. These reactions did not receive a great deal of emphasis during CIAP and thus many gaps in the data base are present. Many interactions of possible importance have not been studied at all while some of those reactions of known importance have not been studied directly. Although the data base has improved somewhat, explicit inclusion of methane oxidation chemistry in assessment models is not yet fully reliable.

In addition to these broad classes of uncertainty, many individual reactions such as the formation of nitric acid from NO_2, are of great importance in the models and subtle changes in their accepted rates can have profound effects. Also, many of the rate coefficients presently used in models have been determined by measuring the rate of disappearance of some easily detected reactants. There is clearly a need for firm quantitative identification of product formation for both kinetic and photochemical processes; otherwise erroneous species production rates may be computed in model calculations.

3.1.2 Uncertainties in Atmospheric Measurements

Field measurements of stratospheric species perform three important functions:

(a) Measurements of some species over an extended period of time are necessary to produce an adequate data base for future reference. In this regard, the monitoring of stratospheric ozone in a manner which ensures comparability over a long time base may be considered as the highest priority objective of any program concerned with ozone depletion.

(b) Measurements of selected species (such as NO, NO_2, HNO_3) may be used to test or validate atmospheric models sufficiently well developed to predict chemical partitioning or equilibrium ratios.

(c) Measurements of some inert constituents or family-related total concentrations of reactive constituents (such as total odd nitrogen) may be used to calibrate transport parameterization in 1, 2, or 3-dimensional models.

Uncertainties present in all three categories have prevented field measurements from being used to their optimal capability. For example, although ground based Dobson spectrophotometric observations of ozone provide the most complete ozone record available, their inter-calibration was not accomplished with the frequency now realized to be necessary. As a result, past data from some stations require corrections which are time-consuming and laborious.

In a similar vein, in situ rocketsonde measurements* of ozone are accomplished by different experimenters with different techniques and/or instrumentation and different numerical procedures. There is a need to intercompare all existing rocketsonde measurements in order to understand the variabilities in them.

With specific regard to the aircraft problem, in situ measurement of the partitioning of NO_x species among NO, NO_2, HNO_3, $ClONO_2$, HO_2NO_2 and N_2O_5 is directly applicable to the validation of atmospheric models used for assessment. There appears to exist a substantial discrepancy between measurement and theory for HNO_3, the principal species through which aircraft nitrogen oxide emissions are removed from the atmosphere. Most existing models tend to overestimate the total HNO_3 column abundance. Furthermore, the HNO_3 to NO_2 ratio is also overestimated. The severity of this discrepancy is dependent upon the specific set of measurements used for comparison since different such sets also tend to disagree with each other. No single set, however, can be considered to be reliable, and the development of accurate in situ techniques to provide such reliability is of utmost importance.

Another serious anomaly also of concern to the aircraft problem is the inability to explain the natural distribution of water vapor. This species is considered to be the key to understanding the transport characteristics of the lower stratosphere which comprises the aircraft domain. Present models are unable to explain the measured water vapor concentrations since the observed water content of the stratosphere is much lower than model predictions. This represents a notable deficiency in most models since the water vapor distribution must be artificially fixed thereby possibly obscuring some important chemical or physical effect.

*Rocket ozone, as well as Dobson total ozone, measurements are very important even for satellite measurements in that they provide the vitally-needed "ground-truth" verification.

3.2 Uncertainties in Atmospheric Transport.

The most serious deficiency in the 1-D models, which have been used to date for aircraft assessment, is their inherent inability to model atmospheric transport properties adequately. This is so because a 1-D model allows variation in atmospheric properties only in the vertical dimension while both the natural distribution of ozone (i.e., its latitudinal and seasonal variabilities) and the aircraft injection are essentially two-dimensional in nature. The latter is a function of altitude and latitude (e.g., the concentration along the trans-Atlantic corridor) and occurs in a region of the atmosphere where horizontal transport, especially across the latitudes, plays a dominant role (i.e., in the vicinity of the tropopause and in the lower stratosphere). Thus, the greatest uncertainty in 1-D models for the aircraft case is the lack of resolution of latitudinal effects. Even though 1-D models will continue to be used for preliminary assessments, such as for the advanced supersonic or hypersonic transport, and for various diagnostic studies which are directed at a quantification of model sensitivity to changes in input data, reliable aircraft assessments can be achieved only with 2-D models. The cumulative effect of NO_x injections, as inferred from 1-D models on ozone, is presently believed to be small due to an essentially mutual cancellation of ozone increase in lower altitudes against ozone decreases higher. The following considerations must be kept in mind in this context:

(a) This "no change" one-dimensional result may be so artificial as to be meaningless. That is to say, in the real atmosphere, the balancing of the two effects may not occur in the same place. Thus, it is possible that ozone reduction may indeed be experienced at some latitudes.

(b) The redistribution of ozone may induce unique effects on other atmospheric characteristics such as circulation and heat balance (in other words, climate). There are no models sufficiently developed to address this issue.

(c) The increase in tropospheric ozone may have some degree of adverse effect on agriculture and human health. It is, therefore, of utmost importance to quantify such an increase for all projected fleet emissions. Ground level effects are usually predicted poorly since, for example in Figure 4, current models set boundary conditions at the ground; and models become less reliable as such boundaries are approached.

Uncertainties in present 2-D models and requirements for future development are now being addressed under HAPP. Computational limitations have historically prevented the inclusion of an adequate set of chemical reactions for assessment purposes. Although this situation is gradually being improved, much work remains. Atmospheric transport refinements, the great advantage of 2-D models, have not yet been demonstrated to be fully consistent. Efforts are underway to address this deficiency. Both theoretical and numerical inadequacies have been identified.

3.3 Sensitivity to Other Anthropogenic Perturbations.

Simultaneous anthropogenic emissions of other substances may profoundly affect NO_x emissions considered in isolation. Just as chlorofluorocarbon emissions have acted to decrease model sensitivity to NO_x, other emissions such as carbon dioxide, sulfur compounds, methane, or brominated organic compounds may also alter the qualitative nature of the effect. Studies have been initiated in this regard with the inclusion of temperature feedback effects and the simultaneous injection of H_2O.

3.4 Uncertainties in Forecast Pollutant Levels due to Aircraft Exhaust Emissions.

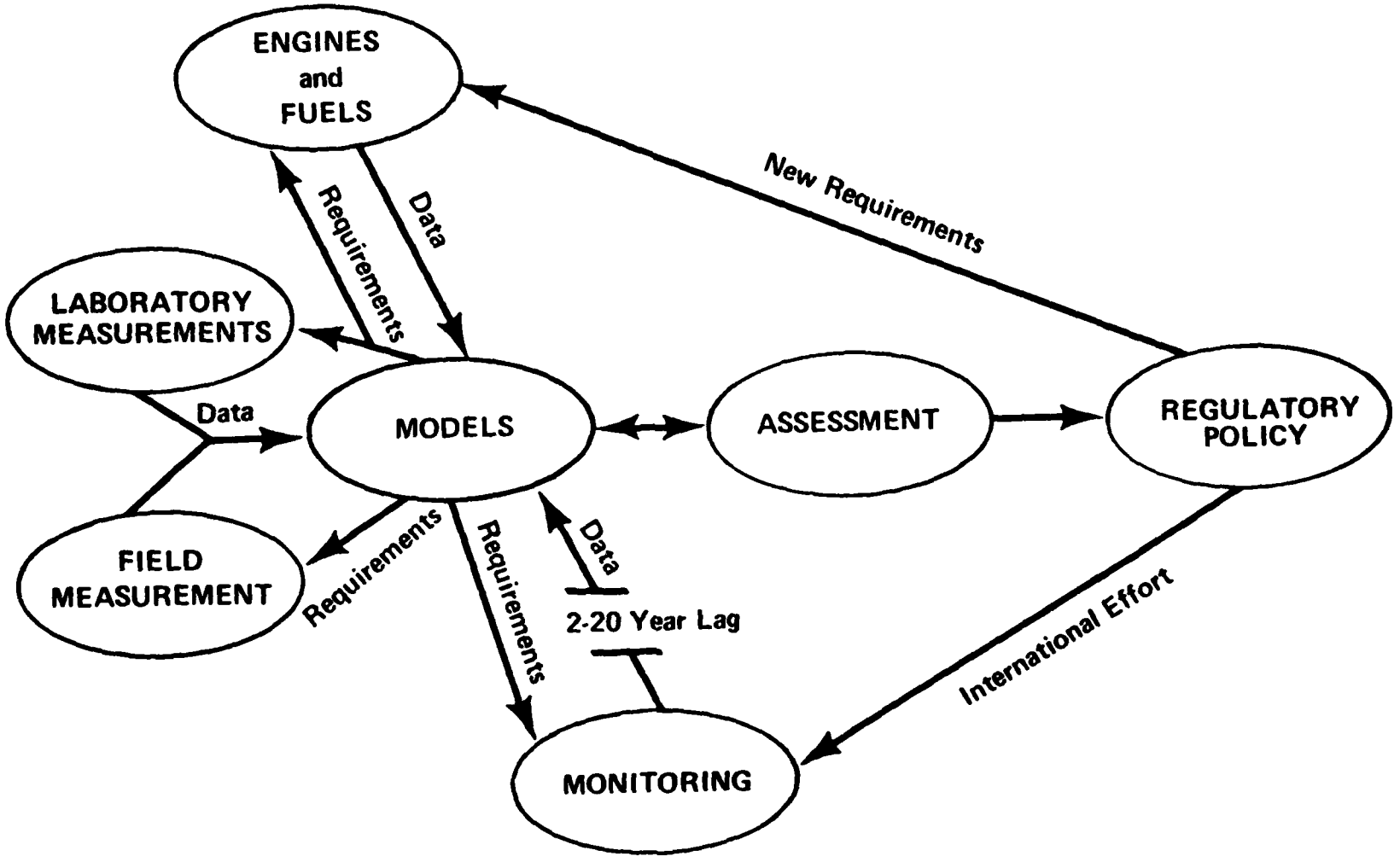
A final uncertainty related to the FAA mission is the determination of the emission characteristics of present and future internal combustion jet engines. In the past, NO_x concentrations measured in the nozzle exhaust have demonstrated severe disagreements related to the measurement technique. In-situ probe measurements tend to show substantially lower emission concentrations of NO_x than remote, optical techniques. The precise value of NO_x emitted per weight unit of fuel consumed is of great importance to the assessment of total fleet impact. Hence the resolution of this uncertainty has become a major focal point of the High Altitude Pollution Program and is nearing completion.

4.0 ACCOMPLISHMENTS OF THE FEDERAL AVIATION ADMINISTRATION/HIGH ALTITUDE POLLUTION PROGRAM

The High Altitude Pollution Program of the Federal Aviation Administration is organized, as shown in Figure 5, under seven major program areas. The primary objective of HAPP is to define policy options if and when regulatory actions appear to be necessary to prevent adverse environmental effects. In order to define such options, a comprehensive assessment of all technical issues will be necessary. Although assessment is necessarily an ongoing programmatic effort at present, a final assessment will constitute the penultimate conclusion of the overall program.

The primary assessment tool, as stated earlier, is the atmospheric model which occupies the central focus of Figure 5. The model is based upon data from engine emissions estimates, laboratory measurements, field measurements, and monitoring efforts by other agencies and international programs. Conversely, model results also guide other program elements by defining specific requirements for new initiatives.

FIGURE 5



HAPP PROGRAM ELEMENTS

4.1 HAPP Scientific Advisory Committee.

In order to assist the HAPP management in formulating technical objectives and evaluating their results, the HAPP Scientific Advisory Committee has been formed. This committee is composed of individuals of widely diverse expertise each eminent in his or her particular discipline. A future and equally important function of the committee, as representative of the technical community, will be to provide their perspective on any policy implications which may result from the HAPP effort. A description of the committee charter and its membership is contained in Appendix I.

4.2 HAPP Studies.

Appendix II lists all efforts initiated or continuing in FY-1979. Those studies planned for FY-1980 are also shown. Some of the most important studies, as they relate to the resolution of uncertainties, are discussed in more detail below.

4.2.1 Laboratory Studies.

4.2.1.1 Chemical Kinetics

Individual laboratory studies are intended to address uncertainties in kinetics and photochemistry, for both tropospheric and stratospheric applications with equal balance. Priorities are selected on the basis of model importance and estimates of the reliability of extant data. An index of reliability is obtained from an ongoing effort to compile and critically evaluate chemical and photochemical parameters by the National Bureau of Standards Data Evaluation Center. This effort, begun during CIAP, continues to be the most comprehensive data evaluation compilation available.

Other tropospheric and lower stratospheric processes which have been studied involve the chemistry and photochemistry of peroxynitric acid, HO_2NO_2.

The kinetics of hydroperoxyl radical reactions will be studied with particular emphasis on mechanistic effects which may necessitate the use of pressure and inverse temperature dependencies in models. Interactions of HO_2 with a wide variety of stratospherically important species are being followed by use of LMR detection in an ongoing study at Cambridge University. Theoretical analysis of quantum-statistical effects which may define a complex mechanism is being undertaken at the National Bureau of Standards. The Bureau is also performing a study of isotopic exchange between HO_2 and ^{18}OH which may reveal the presence of a collision complex intermediate.

4.2.1.2 Methane Oxidation Chemistry

Kinetic studies to improve the reliability of the methane oxidation sequence which plays a major role in the troposphere have included the following:

$$CH_3O + O_3 \longrightarrow \text{Products}$$

$$CH_3O + O_2 \longrightarrow CH_2O + HO_2$$

$$CH_3O_2 + NO \longrightarrow NO_2 + CH_3O$$

$$CH_3O_2 + NO_2 \xrightarrow{M} CH_3O_2NO_2$$

$$H_2CO \xrightarrow{h\nu} \text{Products}$$

4.2.1.3 Heterogeneous Removal Processes

Heterogeneous removal processes are being quantified and parameterized for model input for the surface-catalyzed hydrolysis of N_2O_5 and for the rainout/washout of the family of NO_x species. The latter also involves a parallel field study program and the development of a model which will be used to produce regional and global rainout rates. (Rainout/washout processes are sources of uncertainty in almost all models.)

4.2.2 Field Measurements.

4.2.2.1 Odd Nitrogen Species

The most significant undertaking in the field measurement program has been the completion of a feasibility study for a measurement technique or combination of techniques which can give reliable in-situ values for total odd nitrogen (NO, NO_2, HO_2NO_2, HNO_3, N_2O_5, and $ClONO_2$). Measurements of total odd nitrogen at selected locations and times may be used to calibrate transport coefficients essential in defining the distribution of aircraft emissions. Furthermore, a measure of total odd nitrogen gives directly the expected relative increase over background values for future fleet projections. The preferred measurement technique was concluded to be a hybrid system of chemiluminescence coupled with a photolytic/pyrolytic decomposition chamber.

Much progress has also been made in the development of tunable laser diodes, jointly undertaken with NASA, which can be used to measure individual in-situ concentrations of NO_x species. This may resolve many current discrepancies concerning the partitioning of NO_x and provide further information for model testing and validation.

4.2.2.2 Atmospheric Ozone

Intercomparison of instrumentation has been a major focal point of the field measurement program over the past two years. The FAA has continued to partially support the intercalibration of Dobson spectrophotometers being carried out by the National Oceanic and Atmospheric Administration. In cooperation with the World Meterological Organization and the National Aeronautics and Space Administration, the FAA has recently completed the first international intercomparison of rocketborne ozonesondes at the Wallops Island launch facility of NASA. Participants included Australia, Canada, India, Japan, and the United States.

While continuing to develop jointly with NASA, the capability to obtain total ozone data from the 9.8 micron infrared radiances measured by the Defense Meterological Satellite Program's Block 5-D series, the FAA has also initiated an effort to intercompare such data with other satellite observations in cooperation with Department of Energy/Lawrence Livermore Laboratory, NASA and NOAA. Total ozone measurements from Nimbus 7 (NASA), Tiros N (NOAA), and the Block 5-D series will be compared over a common global grid network.

4.2.2.3 Stratospheric Water Vapor

The continuation of water vapor measurements by frost point hygrometry and the development of new and more versatile instrumentations such as by photofragment fluorescence for stratospheric water vapor has continued to be a high priority item in the field measurement program. The FAA has also supported the development of water vapor measurements by cryogenic collection of atmospheric samples and subsequent analysis in the laboratory at the National Center for Atmospheric Research. The FAA has played a role in interim support of the frost point hygrometry water vapor measurement program as the lead agency has changed from the Naval Research Laboratory to National Oceanic and Atmospheric Administration (NOAA). Having supported the development and preliminary testing of the photofragment fluorescence technique, current plans include a series of flights for the intercomparison of the two methods. If successful, the latter will be able to function at significantly higher altitudes than the frost point hygrometric technique. In addition, intercomparison flights with the frost point hygrometry, photofragment fluorescence and cryogenic collection techniques are planned.

4.2.2.4 Odd Hydrogen Species

Development of a new instrument to determine the in situ concentration of gas phase hydrogen peroxide (HO_2O_2) in the upper troposphere and lower stratosphere is being supported. The instrumentation operates on the principle of the chemiluminescent oxidation of luminol by hydrogen peroxide in the presence of a metal catalyst. Initial testing of this system is scheduled onboard an aircraft in early 1980 with subsequent balloon flights during the summer of 1980.

4.2.3 Modeling.

The 1-D model has been the primary assessment tool for aircraft environmental effects. The major portion of the 1-D modeling effort has been performed by the Lawrence Livermore Laboratory (LLL) of the Department of Energy (DOE). Assessments have been developed for potential effects of subsonic and supersonic fleets and for hypothetical hydrogen-fueled hypersonic fleet. Studies have been made of the effects of uncertainties in chemical rate coefficients, vertical transport coefficients, sensitivities to chemical reactions, temperature feedback, hydrostatic adjustments, and various other model parameters. The results of these studies are summarized below.

(a) Subsonic aircraft fleets projected to the year 1990 are estimated to cause an increase in hemispheric mean total ozone of less than 2 percent as shown in Figure 4. Because of uncertainties in the treatment of poorly understood tropospheric chemistry, these results are suggestive but not definitive of the expected effects.

(b) Supersonic transport fleets of sizes in the range of 750 - 1,000 "Concorde-like" aircraft are estimated to cause an increase in total ozone of less than 1.5 percent depending on specific characteristics for flights up to 20 km.

(c) Emissions from a hypothetical fleet of hypersonic transports (1,000 flights per day) are estimated to cause 0.2 percent reduction in total ozone.

(d) For subsonic and supersonic transport fleets, reductions in NO_x emission rate have a greater effect on ozone change than does a similar percent reduction of H_2O emission.

(e) The increase in total ozone due to a NO_x injection increases as the ClO_x concentration increases.

(f) An analysis of the effects of some plausible reactions and photochemical mechanisms which are not currently included in models shows that stratospheric injections of NO_x could lead to a slight decrease in total ozone.

(g) Temperature feedback and hydrostatic adjustment have a small but not insignificant effect on the computed change in total ozone. Both of these feedback mechanisms tend to increase the change in column ozone for aircraft NO_x injections. Changes in local ozone, for example at 35 km and above, are far more sensitive to such feedback mechanisms. This has important implications for certain monitoring programs.

(h) A variation in solar UV flux of approximately 30 percent which is possible in the 11-year solar cycle can lead to local ozone changes as large as 10 percent near 35 km and total column ozone changes of 5 percent. Detection of anthropogenic perturbations must be evaluated against this variability.

The development of 2-D models has paralleled that of 1-D. The FAA has supported the development of two particular models - the Aerospace Corporation 2-D model and the Crutzen 2-D model. The major development in both models has been the recent inclusion of chlorine chemistry, a prerequisite for reliability in the context of present understanding. The 2-D calculations show qualitative agreement with 1-D models; but specific latitudinal and seasonal effects are not yet firmly characterized.

4.2.4 Engine Emissions.

The most substantive development in the engine emissions program has been the resolution of a long-standing incompatibility between measurements of NO_x emissions by optical and probe chemiluminescence methods. Probe measurements generally appeared to give a lower NO_x emission index than optical techniques implying possible surface catalytic effects on the probes.

However, several probe studies performed under widely varying conditions failed to show any inconsistencies which would be characteristic of surface loss. On the other hand, parallel theoretical studies on the parameterization of the optical properties of NO_x constituents have shown that the inversion technique used in optical measurement studies may be in error. At present, these studies appear to show that the probe technique should be the preferred method for collecting emission index data.

4.2.5 Climate Effects.

Quantitative effects of aircraft emissions on surface temperature remain highly uncertain. Using the 1-D model results for a canonical fleet*, the change in column ozone would result in a change in surface temperature of less than 0.1K for both 17 and 20 km injections. The extent to which a detailed consideration of ozone redistribution would affect this result is unclear.

Radiative effects from H_2O, SO_2 and NO_2 also result in surface temperature changes of less than 0.1K. The latitudinal gradient of any such effects is now being investigated.

4.3 Skin Cancer Studies.

Although no actual studies have been or will be initiated by the FAA, a review of the results from ongoing assessment efforts indicates the following:

*See Footnote on Page 4.

(a) The hypothesis that solar ultraviolet radiation is a dominant factor in the induction of squamous and basal cell carcinomas in predominantly white populations is strongly supported by an examination of available worldwide epidemiological data on non-melanoma.

(b) A very large number of inexplicable anomalies of various kinds are found in the worldwide data which are inconsistent with the hypothesis that solar ultraviolet radiation is a significant factor in the induction of malignant melanoma, leading to the conclusion that the primary causes for this class of tumors may be elsewhere.

(c) The biological amplification factor for basal and squamous cell carcinomas is equal to or greater than unity but it is unlikely that it exceeds a value of 2. Determination of this factor is highly complex and uncertain.

5.0 FUTURE STUDIES

It is anticipated that the final year of effort will be dedicated to an assessment of all contemporary knowledge of aircraft effects on atmospheric ozone and climate. In order to arrive at a state of understanding that sufficient confidence can be placed in such an assessment, several elements of HAPP require further development.

5.1 Laboratory Studies.

The most important issue to be resolved in laboratory experimental studies is that of pressure and inverse temperature effects on bimolecular radical-radical reactions. Some important reactions have already demonstrated such effects and, thus, each remaining reaction to which the model is sensitive must be explored on a case-by-base basis.

A second priority, which is somewhat unique to the aircraft problem, involves the systemmatic improvement in the data base for tropospheric kinetic and photochemical processes. The efficiency with which NO_x catalyzes the production of ozone in the troposphere may be reduced by many reactions which are not well studied or for which no data exist at all. Although urban smog chemistry has been studied in great detail, the methane oxidation chain characteristic of the "clean" troposphere is still ill-characterized.

5.2 Field Measurements.

Two primary objectives for the assessment of aircraft perturbation which remain outstanding are:

(a) To define the distribution of NO_x in space and in time; and

(b) To test or validate assessment models.

The first is essential in quantifying the expected increases above background which will accrue from future aircraft emissions; NO_x distributions also offer an alternative way of calibrating multidimensional transport parameterizations. The second is an integral part of the scientific method and the logical foundation on which model prognostication must be based.

The extension of preliminary feasibility concepts for total NO_x measurement to a prototype measurement package is now in planning. It is expected that a demonstration flight can be accomplished by 1982. A cost effective measurement strategy which yields the optimum data base will be developed within this timeframe.

One approach to model testing which, because of its direct applicability to aircraft problem, will be pursued is the in situ measurement of individual NO_x constituents (such as NO and NO_2) whose relationships are well defined by photochemical theory. The progress of the development of a tunable laser diode measurement system indicates that such measurements may begin for a limited number of species within one year.

5.3 Modeling.

One-dimensional models will continue to be used to explore model sensitivities to various potential changes in input. However, in terms of a final assessment, a more important utilization will be the application of a Monte Carlo variational technique to some 1-D models in order to formally derive a probabilistic description of model output. This analysis will be used to characterize the uncertainty in model predictions. This study has begun and will continue as changes in model inputs occur.

A second major objective is the development of a 2-D model description of aircraft environmental effects. Detailed comparison of existing 2-D model results has demonstrated some inconsistencies which require resolution.

In order to more fully address the relationship between atmospheric models and individual trace species measurements, a study of atmospheric variability and factors which control this variability has been undertaken and will be completed within two years. This study will provide reasonable bounds for expectation values of species concentration measurements and characteristic response times to correlated or anti-correlated fluctuations.

6.0 CONCLUDING REMARKS

Since the termination of CIAP, the scientific understanding of the effect of high altitude cruise emissions on atmospheric ozone has undergone substantial changes. The cumulative effect of including chlorine chemistry, tropospheric effects, and revised chemical rate constants in one-dimensional models is that total column ozone, i.e., that measured from the ground up, is minimally affected and indeed may even increase slightly for foreseeable scenarios. Although the earlier concerns regarding ozone depletion have thus been minimized, uncertainties and anomalies in our present understanding do not allow sufficient confidence to be placed in such results. In order to address these uncertainties, present and future studies by the High Altitude Pollution Program will focus on the following objectives:

(a) The implications of the "no ozone change" must be fully explored with regard to its interpretation by two and three-dimensional models, the impact on tropospheric air quality, and any possible climatic change attending a redistribution of ozone.

(b) Bimolecular chemical reactions which may exhibit pressure and inverse temperature dependencies and the smog chain of methane oxidation must be investigated in greater detail.

(c) Measurements of total odd nitrogen, odd hydrogen and partitioning among these species are needed to support atmospheric models.

(d) Full consideration must be given to the effect of other simultaneous anthropogenic emissions (e.g. ClO_x from chlorofluoromethanes, CO_2) on aircraft perturbations.

(e) A formal quantitative estimate of the uncertainty in model predictions is required. Only within this framework can an objective assessment of costs and benefits of emission reductions, if needed, be obtained.

In addition to the above, it must be realized that large changes in our understanding of aircraft effects have occurred in the recent past due to unanticipated revisions of chemical rate constants, refinements in atmospheric models, and new field measurements. It is prudent to assume that some degree of change may be expected in the future, and, in order to respond to such changes, programs such as HAPP must maintain a flexibility to redirect short term research efforts while, at the same time, accomplishing the overall mission.

REFERENCES

1. CIAP, Report of Findings: The Effects of Stratospheric Pollution By Aircraft, DOT-TSC-75-50, Climatic Impact Assessment Program, U.S. Department of Transportation, Washington, D.C. 20590, December 1974.

2. NRC, Environmental Impact of Stratospheric Flight, Climatic Impact Committee, National Research Council of the National Academy of Sciences/National Academy of Engineering, Washington, D.C., 1975.

3. COMESA, The Report of the Committee on Meteorological Effects of Stratospheric Aircraft, U.K. Meteorological Office, Bracknell, England, 1975.

4. COVOS, Comite d'Etudes sur les Consequences des Vols Stratospheriques, Activites, Societe Meteorologique de France, Boulogne, France, 1976.

5. HAPP, Initial Planning Documentation, High Altitude Pollution Program, Office of Environmental Quality, Federal Aviation Administration/Department of Transportation, Washington, D.C. 20591, June 16, 1975.

APPENDIX 1

HIGH ALTITUDE POLLUTION PROGRAM

SCIENTIFIC ADVISORY COMMITTEE

MEMBERSHIP OF THE COMMITTEE

CHAIRPERSON:

Dr. F. Sherwood Rowland
Professor of Chemistry
Department of Chemistry
University of California
Irvine, California 92717
Chemist

MEMBERS:

Dr. Marcel E. H. Ackerman
Institut d'Aeronomie Spatiale
de Belgique
Avenue Ciculaire 3
B-1180 Brussels, Belgium
Atmospheric Chemist

Dr. Rumen D. Bojkov
Chief Scientist
Atmospheric Science Division
World Meteorological Organization
Case Postale No. 5
CH-1211, Geneva 20 Switzwerland
Meteorologist

Dr. Julius S. Chang
Research Physicist
Theoretical Physics Division
Lawrence Livermore Laboratory
University of California
P.O. Box 808
Livermore, California 94550
Mathematician

Dr. Ralph J. Cicerone
Research Scientist
University of California
Scripps Institute of Oceanography
Ocean Research Division, AO 20
P.O. Box 1529
La Jolla, California 92093
Atmospheric Chemist

Dr. Paul Crutzen
Director
Atmospheric Chemistry Division
National Center for Atmospheric
Research
P.O. Box 3000
Boulder, Colorado 80307
Atmospheric Chemist

Dr. Edwin F. Danielsen
Chief, Theoretical and Planetary
Studies Branch
NASA Ames Research Center
Moffett Field, California 94035
Meteorologist

Professor Dr. Dieter H. Ehhalt
Max Planck Institute
Institut Fur Atmospharische Chemie
Kernforschungsanlaje
517 Julich, West Germany
Atmospheric Chemist

Dr. Harold S. Johnston
Professor of Chemistry
University of California
Department of Chemistry
Berkeley, California 94720
Chemist

Mr. George D. Kittredge
Senior Technical Advisor
U.S. Environmental Protection Agency
Mobile Sources
401 M Street, SW
Washington, D.C. 20460
Engineer

Dr. J. E. Lovelock
Professor
University of Reading
Coombemill, St. Giles-on-the-Heath
Launceston, Cornwall, England
Physicist

Dr. Jerry D. Mahlman
Research Meteorologist
NOAA Geophysical Fluid Dynamics Lab.
Box 308 Princeton University
Princeton, New Jersey 08540
Meteorologist

Dr. Robert J. Murgatroyd
Retired Deputy Chief
Meteorological Office
Government of United Kingdom
London Road, Bracknell (Berks.)
England RG12 2SZ
Meteorologist

Dr. Randall E. Murphy
Research Physicist
Optical Physics, OPR
Geophysics Laboratory
Hanscom AFB Stop 30
Bedford, Massachusetts 01731
Physicist

Dr. Robert C. Oliver
Senior Scientist
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202
Chemist

Dr. A. B. Pittock
Senior Scientist
Division of Atmospheric Physics
Commonwealth Science & Ind.
Research Organization
Government of Australia
P.O. Box 77
Mordialloc, Victoria 3195
Australia
Climatologist

Dr. James N. Pitts, Jr.
Director
Statewide Air Pollution Research Cntr.
University of California
Riverside, California 92521
Chemist

Dr. George D. Robinson
Research Fellow
The Center for Environment and Man, Inc.
275 Windsor Street
Hartford, Connecticut 06120
Meteorologist

Mr. Robert W. Rummel
Retired (Vice President of Research,
TWA)
Robert W. Rummel Associates, Inc.
908 W. Power Road #1189
Mesa, Arizona 85206
Engineer

Dr. Harold I. Schiff
Professor of Chemistry
York University
Department of Chemistry
Downsview, Ontario
Canada M3J 1P3
Chemist

Dr. Arthur L. Schmeltekopf
Division Chief
NOAA Aeronomy Laboratory
Environmental Research Laboratories
National Oceanic and Atmospheric Admin.
Boulder, Colorado 80303
Physicist

Dr. Shelby G. Tilford
Chief, Atmospheric Processes Branch
NASA Headquarters
600 Independence Avenue, S.W.
Washington, D.C. 20546
Physicist

Dr. Adelin Villevieille
Director of Research
Etablissemant d'Etudes et Resch.
Meteorol.
Government of France
73-77 Rue de Sevres
92106 Boulogne, France
Meteorologist

Air Commodore Sir Frank Whittle
Professor
U.S. Naval Academy
10327 Wilde Lake Terrace
Columbia, Maryland 21044
Engineer

CHARTER OF THE COMMITTEE

ORDER **DEPARTMENT OF TRANSPORTATION**
FEDERAL AVIATION ADMINISTRATION

1110.83A

4/14/78

SUBJ: HIGH ALTITUDE POLLUTION PROGRAM SCIENTIFIC ADVISORY COMMITTEE

1. PURPOSE. This order amends the charter of the High Altitude Pollution Program Technical Advisory Committee and changes its name to the HIGH ALTITUDE POLLUTION PROGRAM SCIENTIFIC ADVISORY COMMITTEE.

2. DISTRIBUTION. This order is distributed to division level in Washington and centers and director level in the regions.

3. CANCELLATION. Order 1110.83, High Altitude Pollution Program Technical Advisory Committee, is canceled.

4. BACKGROUND. The Office of Environmental Quality, Federal Aviation Administration (FAA), has established the High Altitude Pollution Program (HAPP) charged with a continuing effort to determine quantitatively the requirements for reduced cruise-altitude exhaust emissions by high altitude aircraft and to determine what regulatory action, if any, is needed to avoid environmental degradation. Accordingly, HAPP must pursue programs related to aircraft engine emissions improvement, aircraft operations, stratospheric measurements, computer modeling of stratospheric processes, laboratory measurements related to stratospheric phenomena, and monitoring of stratospheric phenomena. HAPP has the lead role for the Department of Transportation in carrying out U.S. responsibilities defined in the May 1976 Tripartite Agreement Regarding Monitoring of the Stratosphere, which was signed as a result of one of the actions directed by the Secretary in his February 4, 1976, decision on Concorde. The program must draw upon FAA-sponsored research and on the work of other U.S. and international organizations. It has implications for the aviation manufacturers, airlines, and the general public, both in the United States and internationally. For these reasons, it has been determined necessary to have a HAPP Scientific Advisory Committee to serve the manager of HAPP in assessing and advising on elements of HAPP.

5. OBJECTIVE AND SCOPE OF ACTIVITIES. The objective of the Committee is to review the scope, adequacy, and priorities of HAPP, advise on areas of research that may contribute to the analyses conducted by HAPP, appraise analyses conducted, advise of relevant results in related fields of investigation, and assist in coordinating the relevant programs of other Government agencies with those of HAPP.

6. DESCRIPTION OF DUTIES. The Committee's activity is limited to program review and submission of recommendations and advice to the HAPP program manager.

Distribution: WNC-2; R-1 **Initiated By:** AEQ-10

d. The number of meetings is expected to be one, and possibly two, per year.

e. Detailed minutes shall be kept of each Committee meeting. The minutes shall include the time and place of the meeting; a list of Committee members and staff and agency employees present at the meeting; a complete summary of matters discussed and conclusions reached; copies of all reports received, issued, or approved by the Committee; a description of the extent to which the meeting was open to the public; a description of public participation, including a list of members of the public who presented oral or written statements; and an estimate of the number of members of the public who attended the meeting.

f. The Committee meetings shall be open to the public, and timely notice of such meetings shall be published in the Federal Register at least 15 days before the meeting. The proposed agenda, as well as the time and place of the meeting and information that the meeting will be open to the public, shall be included in the notice which shall be forwarded to the Chief Counsel, Attention: Rules Dockets Section, AGC-24, approximately 30 days before the meeting. Other forms of notice, such as press releases, are to be used to the extent practicable.

g. Members of the Committee who are full-time employees of the United States shall serve without compensation but may be allowed transportation and per diem in lieu of subsistence and other expenses, in accordance with the Department of Transportation's Civilian Travel Regulations.

8. ESTIMATED COST. The estimated annual operating cost of the Committee is $10,000, which includes the travel costs and compensation of the members and miscellaneous costs, such as the printing and issuance of reports. Approximately 0.2 employee-years will be required to support the Committee, including both professional and secretary services.

9. COMPENSATION. Members of the Committee who are not full-time employees of the United States, while attending meetings of the Committee or otherwise engaged in the business of the Committee, shall be entitled to compensation of $100 per day and transportation and per diem in lieu of subsistence and other expenses in accordance with the Department of Transportation's Civilian Travel Regulations.

10. PUBLIC PARTICIPATION. Each Committee meeting shall be open to the public and interested persons shall be permitted to attend, appear before, or file written statements with the Committee, subject to the limitations contained in the exception to the Freedom of Information Act (Title 5, U.S. Code 552(b)) and also subject to limitations of space and time.

APPENDIX II

STUDIES SUPPORTED BY THE

HIGH ALTITUDE POLLUTION PROGRAM

SUMMARY TABLE OF THE

STUDIES SUPPORTED

BY

HIGH ALTITUDE POLLUTION PROGRAM

FAA STUDIES THROUGH FY-1980

Procurement Title	Principal Investigator	Performing Organization	Status
Numerical Simulation of Atmospheric Response	F. Luther	Dept. of Energy/Lawrence Livermore Laboratory	Completed
Numerical Simulation and Ozone Data Analysis	F. Luther	Dept. of Energy/Lawrence Livermore Laboratory	Completed
Latitude Variation in Ozone Reduction	G. Widhopf	USAF SAMSO/Aerospace Corporation	Completed
International Air Traffic Forecast	R. Pozdena	SRI International	Completed
Stratospheric Emissions from Aircraft Operations	P. Athens	Environmental Protection Agency/A. D. Little Company	Completed
Analysis of Fuel Usage	P. Zegan	Eastern Airlines	Completed
Laboratory Study of Chemical Reactions	E. Kaiser	Ford Motor Company	Completed
Measurement of $O(^1D)/N_2O$ and HNO_2/O_3 Kinetics	A. Fontijn	Aerochem Research Laboratories	Completed
Heterogeneous Decomposition of Ozone on Sulphuric Acid at Stratospheric Temperatures	A. Harker	Rockwell International	Completed

FAA STUDIES THROUGH FY-1980
(Continued)

Procurement Title	Principal Investigator	Performing Organization	Status
NO_2 Photolysis	J. Davenport	SRI International	Completed
Reaction Rate Data Tabular Input	D. Garvin	Department of Commerce/NBS	Completed
Critical Analysis of Field Measurement Data	R. Penndorf	Dr. R. Penndorf, Consultant	Completed
Analysis of Ozone and Water Vapor Field Measurement Data	R. Penndorf	Dr. R. Penndorf, Consultant	Completed
Processing, Reduction, and Data Analysis of April and May 1975 CIAP Airstream Data	P. Guthals	Department of Energy/ Los Alamos Scientific Laboratory	Completed
Balloon Launch, Tracking, and Recovery Costs for NO Detector Flight to 45 km	Commander W. Smith	Department of Defense/ Office of Naval Research	Completed
Analysis of Measurement Requirements	R. Penndorf	Dr. R. Penndorf, Consultant	Completed
Trace Gas Analysis of Concorde Air Samples	R. Rasmussen	Oregon Graduate Center	Completed
Data Interpretation of Measurements of Trace Gases	D. Murcray	University of Denver	Completed

FAA STUDIES THROUGH FY-1980
(Continued)

Procurement Title	Principal Investigator	Performing Organization	Status
Assessment of Stratospheric Effects and Uncertainties	R. Oliver	Institute for Defense Analyses	Completed
Study of the Aircraft Effects on Climate	A. Hecht	National Science Foundation/ Climate Research Board	In Progress
Atmospheric Mechanisms	G. Robinson	Center for Environment and Man, Inc.	In Progress
Stratospheric-Tropospheric Exchange Processes	E. Danielsen	Oregon State University	In Progress
Stratospheric Studies Using the Crutzen Two-Dimensional Model	P. Crutzen	Colorado State University	In Progress
Two-Dimensional Model Studies	G. Widhopf	USAF SAMSO/Aerospace Corporation	In Progress
Study of Atmospheric Modeling and DMSP Satellite Ozone Data	F. Luther	Department of Energy/ Lawrence Livermore Laboratory	In Progress
Assess the Nature of Local Variability of Trace Species of Stratospheric Importance	R. Gelinas	Science Applications, Inc.	In Progress
Nitric Oxide Measurement Study	M. F. Zabielski	United Technologies Research Center	In Progress

FAA STUDIES THROUGH FY-1980
(Continued)

Procurement Title	Principal Investigator	Performing Organization	Status
Laboratory Chemistry Studies	D. Kley	NOAA/Aeronomy Laboratory	In Progress
Laboratory Study of Chemical Reactions	H. Schiff	York University	In Progress
Measurement of Perhydroxyl Raction Rates	B. Thrush	University of Cambridge	In Progress
Kinetics of Heterogeneous Hydrolysis of Dinitrogen Pentoxide	A. Harker	Rockwell International	In Progress
Direct Determination of the Rate of Reactions of Methoxy Radicals with Molecular Oxygen and Ozone	H. Radford	Smithsonian Institution/ Astrophysical Observatory	In Progress
Direct Determination of the Rate of Reaction of CH_3O_2 with NO	J. Heicklen	Pennsylvania State University	In Progress
Measurement of the Rate of Reaction of CH_3O_2 with NO_2	R. H. Wine/ A. R. Ravishankara	Georgia Tech Research Institute	In Progress
Evaluation of Chemical Reaction Rate Data and Photochemical Data for Atmospheric Modeling	R. Hampson	Department of Commerce/NBS	In Progress
Theoretical Treatment of Pressure Dependent Reactions	W. Tsang	Department of Commerce/NBS	In Progress

FAA STUDIES THROUGH FY-1980
(Continued)

Procurement Title	Principal Investigator	Performing Organization	Status
Study of the Mechanism of the Reaction of *HO* with HO_2	M. Kurylo	Department of Commerce/NBS	In Progress
Measurement of the Photolytic Parameters for Pernitric Acid	M. Molina	University of California	In Progress
Measurement of the Photolytic Parameters for O_3	J. Davenport	SRI International	In Progress
Measurement of Reaction Rates for Dernitric Acid with OH and $O(^3P)$	J. R. Barker	SRI International	In Progress
Measurement of the Photolytic Parameters for Formaldelyde	P. Warneck	Max Planck Institut für Chimie	In Progress
Measurement of the Rate of *OH + ClO*	R. Young	Xonics, Inc.	In Progress
Measurement of Stratospheric H_2O	J. Mastenbrook	Naval Research Laboratory	In Progress
Development of a Stratospheric Measurement System	N. Macoy	Perkin-Elmer Corporation	In Progress
Analysis and Intercomparison of Ozone Measurements from Dobson Instruments	W. Komhyr	NOAA/Environmental Research Laboratory	In Progress
Investigation of a Global Transport Experiment	P. Guthals	Department of Energy/ Los Alamos Scientific Laboratory	In Progress

FAA STUDIES THROUGH FY-1980
(Continued)

Procurement Title	Principal Investigator	Performing Organization	Status
Cooperative Stratospheric Aerosol Research Program	D. Hofmann	University of Wyoming	In Progress
Measurement to 45 km Using Cryogenic Sampling and Other Techniques	L. Heidt	National Science Foundation/ NCAR	In Progress
In Situ Measurements of NO, NO_2 and N_2O_5 in the Stratosphere from Balloons	H. Schiff	York University	In Progress
Development of Advanced Instrumentation Tunable Double Heterostructure Laser Diodes	F. Allario	NASA/Langley Research Center	In Progress
Investigation of Tropospheric Rainout Processes	S. Schwartz	Department of Energy/ Brookhaven National Laboratory	In Progress
Development of H_2O_2 Measurement Instrumentation	G. Kok	Harvey Mudd College	In Progress
International Intercomparison of Rocketborne Ozonesondes	R. Bojkov	World Meteorological Organization	In Progress

FAA STUDIES THROUGH FY-1980
(Continued)

Procurement Title	Principal Investigator	Performing Organization	Status
International Development and Flight Test of a Balloon-Borne Tunable Laser Diodie Spectrometer System for Strotospheric Measurements	W. Evans/ H. Schiff	Canadian Atmospheric Environment Service	In Progress
Concorde Whole Air Sampling	R. Rasmussen	Oregon Graduate Center	In Progress
Comprehensive Set of Trace Measurements in the Southern Hemispheric Stratosphere	I. Galbally	Australian Commonwealth Scientific and Industrial Research Organization	In Progress
Analysis of Aircraft Effects	R. Oliver	Institute for Defense Analyses	In Progress

DESCRIPTION OF THE

STUDIES SUPPORTED

BY

HIGH ALTITUDE POLLUTION PROGRAM

MODELING: STUDIES COMPLETED

(1) DOT-TSC-(RA)-76-1
Department of Energy/
Lawrence Livermore Laboratory

Numerical simulation of Atmospheric Response

F. Luther

August 1975 to June 1976

To refine the LLL one-dimensional model for the stratosphere in the areas of photochemical kinetics, transport kinetics and radiation transfer.

---

(2) DOT-FATQWAI-653
Department of Energy/
Lawrence Livermore Laboratory

Numerical Simulation and Ozone Data Analysis

F. Luther

July 1976 to September 1978

To continue model refinement started under DOT-TSC-(RA)-76-1 with improved tropospheric chemical cycles. Also, to process ozone data obtained from the USAF Block 5-D satellite and perform global data analysis.

FAA-EQ-77-6 ADA 040 627	Lawrence Livermore Laboratory First Annual Report to the High Altitude Pollution Program (June 1976)
FAA-EQ-78-09 ADA 057 139	Annual Report of Lawrence Livermore Laboratory to the High Altitude Pollution Program 1977 (May 1978)
FAA-EE-79-04 ADA 069 127	Annual Report of the Lawrence Livermore Laboratory to the FAA on the High Altitude Pollution Program 1978 (September 1978)

---

(3) DOT-TSC-(RA)-76-10
USAF SAMSO/Aerospace Corporation

Latitude Variation in Ozone Reduction

G. Widhopf

September 1975 to December 1976

To refine the transport parameterization in the Aerospace two-dimensional model using available tracer data and use the refined model to compare predictions with actual distributions of atmospheric trace species.

MODELING: STUDIES IN PROGRESS

(1) DOT-FA78WAI-911
National Science Foundation/
Climate Research Board.

Study of the Aircraft Effects on Climate

A. Hecht

Through the Climate Research Board of the National Academy of Sciences, to assess the impact of high-altitude aviation on the climate.

---

(2) DOT-FA77WA-4055
Center for Environment
and Man, Inc.

Atmospheric Mechanisms

G. Robinson

In light of recent chemical kinetics data, to reexamine the chemistry and diffusion of aircraft exhaust trails and include interpretations of available trace species measurements and transport parameterizations.

---

(3) DOT-FA77WA-3992
Oregon State University

Stratospheric-Tropospheric Exchange Processes

E. Danielsen

To develop, test and document an objective methodology based on routinely available synoptic meterological data for the quantitative determination of stratospheric-tropospheric mass exchange. To use this methodology to determine all relevant transport parameters for use in two-dimensional models of the stratosphere.

---

(4) DOT-FA77WA-4039
Colorado State University

Stratospheric Studies Using the Crutzen Two-Dimensional Model

P. Crutzen

To refine the Crutzen model of the stratosphere and to use it to study trace species distributions, water vapor budget and the effects of high-altitude aviation on stratospheric ozone.

(5) DOT-FA77WAI-720 — Two-Dimensional Model Studies
USAF SAMSO/Aerospace Corporation

G. Widhopf — December 1976 to June 1980

To continue to refine the Aerospace two-dimensional model to incorporate chlorine chemistry, multiple scattering, and to use the model to study the effect of high-altitude aviation on stratospheric ozone.

FAA-EE-79-07
ADA 073 566
Two-Dimensional Description of the Natural Atmosphere Including Active Water Vapor Modeling and Potential Perturbations due to NO_x and HO_x Aircraft Emissions (April 1979)

---

(6) DOT-FA79WAI-034** — Study of Atmospheric Modeling and DMSP Satellite Ozone Data
Department of Energy/
Lawrence Livermore Laboratory

F. Luther

To develope and maintain a state-of-the-art capability presently existing at LLL to numerically model all atmospheric phenomena relevant to HAPP requirements. Also, to receive and reduce ozone data sensed by the USAF Block 5-D satellite.

---

(7) DOT-FA79WA-4306 — Assess the Nature of Local Variability of Trace Species of Stratospheric Importance
Science Applications, Inc.

R. Gelinas

To study the local variability of trace species concentrations so that their atmospheric measurements may be used to (a) verify one- and two-dimensional stratospheric models, (b) develop an improved stratospheric measurement strategy, and (c) estimate the probable range of inaccuracies inherent in present stratospheric ozone models.

ENGINES AND FUELS: STUDIES COMPLETED

(1) DOT-FA75WA-3574 — International Air Traffic Forecast
SRI International

R. Pozdena — January 1976 to September 1976

To produce a world aviation forecast for long-range, high-altitude flights for the years 1975 to 1990 (five year intervals) by aircraft equipment and fleet.

---

(2) DOT-FA76WAI-603 — Stratospheric Emissions from Aircraft Operations
Environmental Protection Agency/ A.D. Little Co.

P. Athens — February 1976 to August 1976

For subsequent use for studies of stratospheric impacts and possible need for aircraft regulations, to determine emission indices for aircraft engines operating above 8 km and provide global emissions loading data.

---

(3) DOT-FA76WAI-603 — Analysis of Fuel Usage
Eastern Airlines

P. Zegan — August 1977 to October 1978

For input to improve forecasts of emissions loading for use in model calculations, to compile forecasts of fuel burn by geographic location and altitude based on aircraft fleet projections through the year 2000.

ENGINES AND FUELS: STUDIES IN PROGRESS

(1) DOT-FA77WA-4081*** — Nitric Oxide Measurement Study

United Technologies Research Center

M. F. Zabielski

Investigate both optical and sample-extractive methods for measuring nitric oxide in combustion systems and define and document the difference between the results from the two methods.

LABORATORY MEASUREMENTS: STUDIES COMPLETED

(1) DOT-TSC-1201
Ford Motor Company

Laboratory Study of Chemical Reactions

E. Kaiser

June 1976 to June 1977

To study the rate of the reaction of HONO + O_3 and $O(^3P) + N_2O_5$.

FAA-EQ-77-7
ADA 046 159

The Kinetics of the Gas Phase Reaction of Nitrous Acid with Ozone (July 1977)

FAA-AEQ-77-12
ADA 046 160

The Kinetics of the Gas Phase Reaction of $O(^3P)$ with N_2O_5 (September 1977)

---

(2) DOT-TSC-1200
AeroChem Research Laboratories

Measurements on $O(^1D)/N_2O$ and HNO_2/O_3 Kinetics

A. Fontijn

June 1976 to June 1977

To measure the branching ratio of $O(^1D) + N_2O$ and the products of the reaction HONO + O_3 over stratospheric temperatures.

FAA-EQ-77-10
ADA 051 427

Measurements on $O(^1D)/N_2O$ and HNO_2/O_3 Kinetics (June 1977)

---

(3) DOT-TSC-1202
Rockwell International

Heterogeneous Decomposition of Ozone on Sulfuric Acid at Stratospheric Temperatures

A. Harker

June 1976 to June 1977

To develop apparatus for generating aerosol mist and to measure the rate of ozone decomposition over the mist.

FAA-AEQ-77-12
ADA 051 504

Heterogeneous Decomposition of Ozone on Sulfuric Acid Surfaces at Stratospheric Temperatures (September 1977)

(4) DOT-TSC-1204 — NO_2 Photolysis
SRI International

J. Davenport — June 1976 to June 1977

To measure the NO_2 photolysis cross-sections and quantum yields between wavelengths 385 to 425 nm and temperatures 200-300 K.

FAA-AEQ-78-05 Determination of NO_2 Photolysis Parameters
ADA 056 843 for Stratospheric Modeling (June 1978)

---

(5) RA 76-13-6400223* — Reaction Rate Data, Tabular Input
Department of Commerce/NBS

D. Garvin — January 1976 to May 1978

This effort includes the following:

1. Review of Atmospheric Rate Constant Data
2. Compilation of $ClONO_2$ Kinetic Data
3. Compilation of Combustion Kinetic Data

NBS Special Publication 513 — Reaction Rate and Photochemical Data for Atmospheric Chemistry (May 1978)

NBS Special Publication 478 — Nitrogen Oxychlorides: A Bibliography on Data for Physical and Chemical Properties of NO, NO_2 and NO_3 (August 1977)

NBS Special Publication 449 — Chemical Kinetics of the Gas Phase Combustion of Fuels

LABORATORY MEASUREMENTS: STUDIES IN PROGRESS

(1) DOT-FATQWAI-733
NOAA/Aeronomy Laboratory

Laboratory Chemistry Studies

D. Kley

To determine in situ J values for O_3, O_2, N_2O, and NO and measure the altitude profiles of H_2O and H_2O_2.

---

(2) DOT-TSC-1203
York University

Laboratory Study of Chemical Reactions

H. Schiff

To determine the reaction rates and products of $O(^1D) + N_2O$ and of $O(^3P) + N_2O_5$.

---

(3) DOT-FA77WA-4054
University of Cambridge

Measurement of Perhydroxyl Reaction Rates

B. Thrush

To measure the absolute rate and temperature dependence of the reactions of HO_2 with HO_2, OH, SO_2, Cl, NO, O_3, Br, and H.

---

(4) DOT-FA79WA-4378
Rockwell International

Kinetics of the Heterogeneous Hydrolysis of Dinitrogen Pentoxide

A. Harker

To determine the rate of formation of nitric acid from dinitrogen pentoxide and water vapor in the presence of simulated stratospheric aerosol surfaces.

---

(5) DOT-FA79WA-4362
Smithsonian Institution
Astrophysical Observatory

Direct Determination of the Rate of Reaction of Methoxy Radicals (CH_3O) with Molecular Oxygen and Ozone

H. Radford

To measure the rate of reaction of methoxy radicals with oxygen and ozone by means of a laser magnetic resonance apparatus.

(6) DOT-FA79WA-4393
Pennsylvania State University

Direct Determination of the Rate Reaction of CH_3O_2 with NO

J. Heicklen

To measure the rate and temperature dependence of the reaction of methyl peroxy radicals with nitric oxide.

---

(7) DOT-FA78WA-4259
Georgia Tech Research Institute

Measurement of the Rate of $CH_3O_2 + NO_2$

P. H. Wine/A. R. Ravishankara

To measure the rate for $CH_3O_2 + NO_2$ over the relevant range of tropospheric temperatures and pressures.

---

(8) DOT-FA79WAI-005*
Department of Commerce/NBS

Evaluation of Chemical Reaction Rate Data and Photochemical Data for Atmospheric Modeling

R. Hampson

To prepare detailed evaluations of NO_x and $O(^1D)$ reactions and to compile an evaluation of all other atmospheric reactions in individual data sheet form.

---

(9) DOT-FA79WAI-026
Department of Commerce/NBS

Theoretical Treatment of Pressure Dependent Reactions

W. Tsang

To apply unimolecular reaction rate theory to possible complex intermediates formed in radical-radical bimolecular reactions.

---

(10) DOT-FA79WAI-112
Department of Commerce/NBS

Study of the Mechanism of Reaction of OH with HO_2

M. Kurylo

To investigate the mechanisms of $OH + HO_2$ using isotopic labeling kinetic studies.

(11) DOT-FA78WA-4248
University of California

Measurement of the Photolytic Parameters for Pernitric Acid

M. Molina

To determine the cross section in the UV and IR for HO_2NO_2 and to deduce quantum yields for its photolytic decomposition.

---

(12) DOT-FA78WA-4263
SRI International

Measurement of the Photolytic Parameters for O_3

J. Davenport

To determine the cross section and quantum yields for O_3 photolysis over the threshold region.

---

(13) DOT-FA78WA-4228
SRI International

Measurement of Reaction Rates for Permitric Acid with OH and $O(^3P)$

J. R. Barker

To determine the rate of reaction of OH and $O(^3P)$ with HO_2NO_2 as a function of temperature.

---

(14) DOT-FA78WA-4264
Max-Plank Institute

Measurement of the Photolytic Parameters for Formaldelyde

P. Warneck

To measure the absorption cross section and quantum yields for HO_2CO as a function of temperature and pressure.

---

(15) DOT-FA78WA-4262
Xonics, Inc.

Measurement of the Rate of OH + ClO

R. A. Young

To determine the rate of reaction of OH with ClO as a function of temperature and pressure.

FIELD MEASUREMENTS AND MONITORING: STUDIES COMPLETED

(1) DOT-FATQWA-3866 — Critical Analysis of Field Measurement Data
Dr. Rudolph Penndorf

R. Penndorf — July 1976 to August 1977

To collect and analyze in a critical manner all field data from one kilometer to the tropopause and also all stratospheric data of importance to HAPP. Ozone data should be assembled to obtain monthly averages and trends.

---

(2) W1-78-3740-1 — Analysis of Ozone and Water Vapor Field Measurement Data
Dr. Rudolph Penndorf

R. Penndorf — April 1978 to December 1978

To review and update results obtained for ozone and water vapor data under contract DOT-FATQWA-3866.

FAA-EE-78-29 Analysis of Ozone and Water Vapor Field
ADA 072 721 Measurement Data (November 1978)

---

(3) DOT-FA76WAI-628 — Processing, Reduction, and Data Analysis of April and May 1975 CIAP/Airstream Data
Department of Energy/
Los Alamos Scientific Laboratory

P. Guthals

To perform data processing of the CIAP/Airstream data and deliver to scientist in charge (Dr. Murcray of the University of Denver) to determine the HNO_3 column density and to compare the results with earlier measurements.

---

(4) DOT-FA76WAI-648* — Balloon Launch, Tracking, and Recovery Costs for NO Detector Flight to 45 km.
Department of Defense/
Office of Naval Research

Commander W. Smith — June 1976 to October 1976

To provide flight services in connection with a balloon launch conducted by the University of Wyoming to detect nitric oxide up to an altitude of 45 km.

(5) W1-76-1085-1
Dr. Rudolph Penndorf

Analysis of Measurement Requirements

R. Penndorf

November 1975 to May 1976

To analyze data obtained under DOT/CIAP and recommend specific requirements for future stratospheric measurements under HAPP.

---

(6) W1-78-3745-1
Oregon Graduate Center for Study and Research

Trace Gas Analysis of Concorde Air Samples

R. Rasmussen

April 1978 to October 1978

To participate in analysis of Concorde air samples and compare with data obtained on same species during previous high altitude flights. Also to evaluate the sampling program and describe needs to obtain the maximum scientific knowledge from the program.

FAA-EE-78-25
ADA 064 905

Concorde Air Sampling Program Intercalibrations and Collaborative Measurements (September 1978)

---

(7) DOT-FA77WA-3949
University of Denver

Data Interpretation of Measurements of Trace Gases

D. Murcray

February 1977 to August 1978

To determine the error in deducing NO and NO_2 altitude profiles from infrared solar spectra obtained at high altitudes during sunrise and sunset.

FAA-EE-78-30
ADA 069 495

On the Interpretation of Infrared Solar Spectra for Altitude Distribution of Atmospheric Trace Constituents (August 1978)

FIELD MEASUREMENTS: STUDIES IN PROGRESS

(1) DOT-FA77WAI-748* — Measurement of Stratospheric H_2O
Naval Research Laboratory

J. Mastenbrook

To design, develop and test a frostpoint hygrometer-type instrument to measure atmospheric water vapor. To continue periodic water vapor measurement presently conducted by NRL and compare data obtained for a period of one year with soundings in the vicinity of Boulder, Colorado.

---

(2) DOT-FA77WA-4080 — Development of Stratospheric Measurement System
Perkin-Elmer Corporation

N. Macoy

To perform a feasibility study to provide a conceptual design with documentation for an instrument to simultaneously measure the odd nitrogen species in the stratosphere. To perform necessary laboratory measurements to verify the critical parts of the measurement system and fabricate a laboratory prototype measurement system to demonstrate feasibility.

FAA-EQ-78-10
ADA 059 330
High Altitude Pollution Program Stratospheric Measurement System Feasibility Study (January 1978)

---

(3) DOT-FA78WAI-850 — Analysis and Intercomparison of Ozone Measurements from Dobson Instruments
NOAA/Environmental Research Laboratory

W. Komhyr

To reprocess total ozone data collected over the past 15 years from the 15 station NOAA Dobson spectrophotometer network. To maintain the world standard calibration instrument and provide calibration for instruments at other stations.

---

(4) DOT-FA78WAI-860 — Investigation of a Global Transport Experiment
Department of Energy/Los Alamos Scientific Laboratory

P. Guthals

To examine possible tracers for a global transport experiment and include considerations of their chemistry and instrumentation for sample collection. Also, to review the scientific value of such an experiment.

(5) DOT-FA76WA-3782
University of Wyoming

Cooperative Stratospheric Aerosol Research Program

D. Hofmann

To perform a joint aerosol measurement program with the University of Leningrad consisting of simultaneous measurements by both groups in the U.S. and the U.S.S.R. In addition, prepare a joint report and provide supporting measurement to NASA's NIMBUS 7 satellite.

FAA-AEQ-78-22 University of Wyoming/Leningrad State
ADA 060 383 University Cooperative Stratospheric Aerosol Research Program (July 1978)

---

(6) DOT-FATQWAI-684
National Science Foundation/ National Center for Atmospheric Research

Measurement to 45 Kilometers Using Cryogenic Sampling and Other Techniques

L. Heidt

To conduct four (2 at the equator and 2 at northern latitudes) atmospheric balloon and aircraft cryogenic sampling missions and provide data analysis.

---

(7) DOT-FA77WA-3931
York University

In Situ Measurements of NO, NO_2 and N_2O_5 in the Stratosphere from Balloons

H. Schiff

To perform four balloon flights to make simultaneous NO, NO_2 and if obtainable N_2O_5 measurements throughout the course of a day. Also, to investigate laser diode technology for measurement of NO and NO_2 to better than 100 pptv.

---

(8) DOT-FA77WAI-722*
NASA/Langley Research Center

Development of Advanced Instrumentation Tunable Double Heterostructure Laser Diodes

F. Allario

Using molecular beam epitaxy techniques, to grow laser fibers, to fabricate lasers from these fibers and test for device characterization.

(9) DOT-FA78WAI-859
Department of Energy/
Brookhaven National Laboratory

Investigation of Tropospheric Rainout Process

S. Schwartz

To review available literature addressing the chemistry of the interaction of nitrogen oxides and oxyacids with atmospheric water. As a result of the review, to perform necessary modeling, laboratory measurements, and field measurements to define the tropospheric rainout removal process.

---

(10) DOT-FA78WA-4232
Harvey Mudd College

Development of H_2O_2 Measurement Instrumentation

G. Kok

To develop instrumentation for the in situ measurement of gas phase hydrogen peroxide in the stratosphere and upper troposphere for concentrations from 0.1 ppbv to 100 ppbv.

---

(11) AIA/CA-12
Memorandum of Agreement with the World Meteorological Organization

International Intercomparison of Rocketborne Ozonesondes

R. Bojkov

To implement an international intercomparison of rocketborne ozonesondes at the NASA/Wallops Flight Center facility in August-October 1979.

---

(12) AIA/CA-13
Memorandum of Agreement with the Canadian Atmospheric Environment Service

International Development and Flight Test of a Balloon-Borne Tunable Laser Diode Spectrometer System for Stratospheric Measurements

W. Evans/H. Schiff

To develop a tunable laser diode spectrometer to measure at least NO and NO_2 in the stratosphere and perform a flight test of the instrument.

(13) DOT-FA79WA-4285
Oregon Graduate Center for Study and Research

Concorde Whole Air Sampling

R. Rasmussen

To conduct whole air samples on not less than 10 concorde flights between Dulles and Heathrow. Perform trace gas analysis on these samples and compare results with data previously obtained.

---

(14) AIA/CA-17
Memorandum of Understanding with the Australian Commonwealth Scientific and Industrial Research Organization

Comprehensive Set of Trace Gas Measurements in the Southern Hemispheric Stratosphere

I. Galbally

To perform six balloon flights to obtain stratospheric measurements including latitudinal, altitudinal, and seasonal and (if possible) diurnal variations of nitrous oxide, nitric oxide, nitrogen dioxide and nitric acid along with ozone, water vapor, CFM's and air temperature in the Southern Hemisphere.

ASSESSMENT, REGULATION, AND COORDINATION: STUDIES COMPLETED

(1) DOT-FA76WA-3757 — Assessment of Stratospheric Effects and Uncertainties

Institute for Defense Analyses

R. Oliver — October 1975 to August 1976

To review the Report of Findings of the DOT/CIAP and other documents concerning stratospheric ozone depletion and to assess effects of high-altitude aircraft on the environment.

FAA-EQ-77-6
ADA 040 638 — Aircraft Emissions: Potential Effects on Ozone and Climate (March 1977)

ASSESSMENT, REGULATION, AND COORDINATION: STUDIES IN PROGRESS

(1) DOT-FA77WA-3965 — Analysis of Aircraft Effects
Institute for Defense Analyses

R. Oliver

To summarize the status of research on the effects of high altitude aircraft operation in the stratosphere. To review the status of modeling efforts and the relationship between ozone amounts, ultraviolet irradiance and skin cancer. To study the atmospheric perturbations caused by atmospheric injection both natural and anthropogenic.

FAA-EQ-78-19 ADA 064 130	On the Linkage of Solar Ultraviolet Radiation to Skin Cancer (September 1978)
FAA-EQ-78-20 ADA 063 650	A Catalog of Perturbing Influences on Stratospheric Ozone, 1955-1975 (September 1978)
FAA-AEQ-78-23 ADA 065 472	The Status of Representative Two-Dimensional Photochemical Models of the Stratosphere and Troposphere as of Mid-1978 (October 1978)
FAA-AEE-78-24 ADA 063 586	Recent Developments in the Estimation of Potential Effects of High Altitude Aircraft Emissions on Ozone and Climate (October 1978)
FAA-EE-79-19	Modeling Differential Exposure and Differential Sensitivities in Non-Melonoma Skin Cancer Incidence (December 1979)

*Funded jointly with the Upper Atmospheric Research Program, Office of Solar and Terrestrial Applications, National Aeronautics and Space Administration (NASA).

**The DMSP Satellite Ozone Data Study was jointly funded with NASA.

***Funded jointly with NASA, Department of Defense (Department of the Air Force and Department of the Navy) and the Environmental Protection Agency.

*U.S. GOVERNMENT PRINTING OFFICE : 1980 0-312-833/6002